Charged kaon condensation in high density quark matter*

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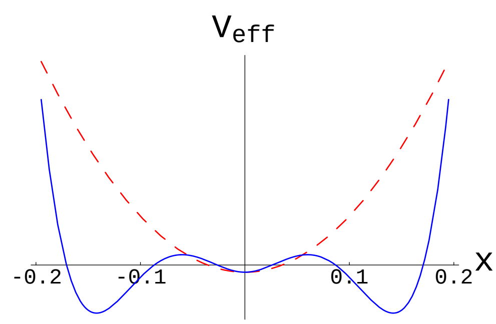
It was realized a long time ago that the attraction between two quarks close to the Fermi surface in high density strongly interacting matter leads to the formation of Cooper pairs of quarks and the spontaneous breaking of color symmetry. This phenomenon was more recently studied using a variety of methods and the main lessons learned in these studies were that i) the gap can be large, up to 100 MeV, ii) in the case of three-flavors of quarks with the same mass the ground state is the so-called color-flavor-locked (CFL) state , and chiral symmetry remains broken at arbitrarily high densities and iii) the low-lying excitations carry the quantum numbers of the pseudo-scalar octet familiar from the zero density case (plus two other scalars related to the spontaneous breaking of baryon number and axial charge) and iv) a form of electromagnetism survives: a combination of the photon and the eight gluon is not "Higgsed" and remains massless in the CFL phase.

The CFL phase responds to mass asymmetries that costs little energy but is not available in the free or two-flavor system : it can condense mesons carrying strangeness, that are particularly light. This was demonstrated in on very general grounds and, in the case of weak coupling, through explicit computations of the response function to mass asymmetries. For realistic values of the quark masses and densities it was found that the K^0 is the meson that condenses. In the CFL phase there is an equal number of quarks of the three flavors, and the system achieves electrical neutrality in the absence of any electrons, making it a perfect insulator. The presence of the K^0 condensate, being neutral, does not change this situation. A *charged* kaon condensate however would change quark matter from a perfect insulator to a (electrical) superconductor. It is a generic feature of charged massless scalars that the strong long wavelength fluctuations of the gauge field lead to condensation of the scalar field (Coleman-Weinberg mechanism. In the CFL+K^0 phase there is one *almost* massless charged scalar field. Its mass comes from isospin breaking contributions coming from the quark mass difference and electromagnetic mass effects. In this paper we consider the competition between the isospin breaking mass terms and the fluctuations of the electromagnetic field in order to determine the fate of the charged kaons and of the possibility of a (electromagnetic) superconducting phase in quark matter.

We show that at asymptotically high densities the "color-flavor-locked + neutral kaon condensate" phase of QCD develops a *charged* kaon condensate through the Coleman-Weinberg mechanism. At densities achievable in neutron stars a charged kaon condensate forms only for some (natural) values of the low energy constants describing the low-lying excitations of the ground state.

Figure 1: Effective potential as a function of $x = \tan(|K^+|/|K^0|)$ for a natural choice of parameters and leading perturbative results for the remaining parameters). The dashed line shows the effective potential without the electromagnetic contribution.



[1] Paulo F. Bedaque, *Phys.Lett. B524 (2002) 137-143*